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R & D STATUS REPORT #4

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Contractor	:	Ortel Corporation
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Principal Investigator	:	Dr. Michael Mittelstein (current) Dr. Nadav Bar-Chaim (initially)
Telephone No.	:	(818) 281-3636
Title of Work	:	"Vertical Emitting, Ring Geometry, Ultra-low Threshold and Ultra-high Speed Quantum Well Lasers for Optical Interconnect"
Reporting Period	:	November 1989 - February 1990

R & D STATUS REPORT #4

November 1989 - February 1990

The following constitutes the status report for work done on Contract No. N00014-88-C-0483 entitled "Vertical Emitting, Ring Geometry, Ultra-low Threshold and Ultra-high Speed Quantum Well Lasers for Optical Interconnect" during the period November 1989 to February 1990.

The main emphasis during this quarter was placed on the following efforts: 1) evaluation of structures suitable for vertically emitting ring lasers; 2) fabrication of gratings on non-planar surfaces; 3) presentation at a DoD Fiber Optics Conference.

Structures for Vertical Emitting Ring Lasers

Several structures can be considered for implementation within the selection of a ring resonator in the plane of the substrate with vertical output coupling. For reasons mentioned previously, the active region is to be a single quantum well centered in an transverse real index of refraction guide. For the lateral structure, a buried heterostructure fabricated by a second growth has been evaluated extensively within this contract so far. However, the complex processing required has lead us to consider alternative structures. The fabrication process for the ring lasers has not included the grating fabrication for vertical output coupling thus far. This added complexity requires a reproducible process for ring fabrication in order to achieve yields beyond those achieved in feasibility demonstration. We intend to investigate within this contract ridge waveguide structures because of their less demanding processing. The addition of the surface grating for vertical emission can be accomplished in several ways.

Second order gratings for vertical emission perpendicular to a single mode waveguide have to be positioned such that the local intensity of the optical field at the position of the grating is high enough for good efficiency with moderate grating depth. Consequently the grating has to be within the waveguiding structure. Basically two options exist:

1) **Grating within semiconductor material.** A grating etched into the substrate and then buried under a single growth layer structure in the GaAs/GaAlAs system is not compatible with forming a waveguide unless the substrate already has an epitaxial GaAlAs layer. In order to define the grating with conventual methods within the semiconductor material requires a two step growth process. The grating is lithographically defined after completion of the first growth, etched and preserved to be buried under the material deposited in the second growth. This second growth is not useful for lateral optical guiding and electrical blocking layers often provided by the second growth, an additional third growth would be required to implement these additional properties.

2) **Grating on semiconductor surface.** A grating etched into the uppermost layer of semiconductor material can be utilized providing that this layer is part of the optical waveguiding structure such that high optical intensity is achieved. The relative low index of refraction outside the semiconductor material provides a strong guiding effect with tends to expel the optical field from the guided mode. However by locating the layer with the grating near the center of the original waveguide and etching the outside layers away adequate optical field intensity can be provided. This leads to a strong modification of the optical mode, but the single mode guiding characteristics can be maintained. Typically the transverse optical mode size inside a GaAs/GaAlAs lasers is in the range of 0.2 to 0.5 μm full width at half maximum intensity. In single quantum well lasers the well is almost always placed in the center of the optical mode. Consequently the layer of the grating has to be placed very close to the well with about 0.1 μm accuracy.

Our plan for the next phase is to demonstrate performance parameters of vertical emitting straight lasers with second order gratings on the semiconductor surface. This is based on our successful demonstration of "fabrication of gratings on non-planar surfaces" described in the following section of this report. The above mentioned required control of the relative layer position is made more demanding by the depth at which the quantum well is typically located: 1 to 2 μm below the top layer of the stack of layers that form the active part of the laser. Consequently a relatively high accuracy etch is required and a step of about 1.5 μm will remain at the transition from the grating region to the active region of the integrated vertically emitting laser. Stop-etch layer technique are appropriate to ease the tight control parameters of the process. This fabrication method leads itself to considering lateral ridge waveguide structures. The ridge waveguide structure utilizes the lateral effective index step resulting from etching away part of the top layers of the transverse waveguide. For a single mode laser waveguide structure a mesa of a few μm width and typically 1 to 1.5 μm height results, where the material is removed on both sides of the laser structure. This lateral waveguide structure is very similar to the described longitudinal integration of a surface grating for vertical emission. We consider combining several processing steps in the integrated fabrication.

Fabrication of Grating on Non-Planar Surfaces

The ability to fabricate surface gratings on a non-planar structure enables the grating fabrication of a vertical emitter after the active part of the laser structure has been completed. The significance is described in the preceeding section "structures for vertical emitting ring lasers" of this report. Achieving grating fabrication on a non-planar surface, allows an uninterrupted growth of the active region of the laser. This greatly reduces the risks in research and development of the fully integrated vertically emitting ring laser.

In order to demonstrate the capability to produce suitable gratings, non-planar substrates were fabricated to simulate the conditions to be expected in laser fabrication. Several methods of preparation for grating definition were investigated and it was found that a tolerable transition zone of width less then 5 μ can be achieved. The small transition zone exhibits no grating. The grating starts rather abruptly at the end of the transition zone without defects. In **Figure 1** the experimental result is illustrated. The SEM photo shows on the right the elevated region simulating the structure embedding the active region of a laser. Towards the center of the figure the vertical step is evident, its height is the upper limited considered for laser fabrication. The left hand side of the figure shows the fabricated grating, its orientation is tilted with respect to the step to demonstrate the ubrupness of the onset for the grating. In the center the transition region is evident. A little bit of transition region is beneficial because partial blocking of the upwards emitted light by the step would cause reduced smoothness in the far field of the vertically emitted beam. In **Figure 2** the considered overall laser structure is shown. The otherwise planar surface exhibits a "hole" whose bottom is the grating. The figure is not to scale, the real design appears nearly flat.

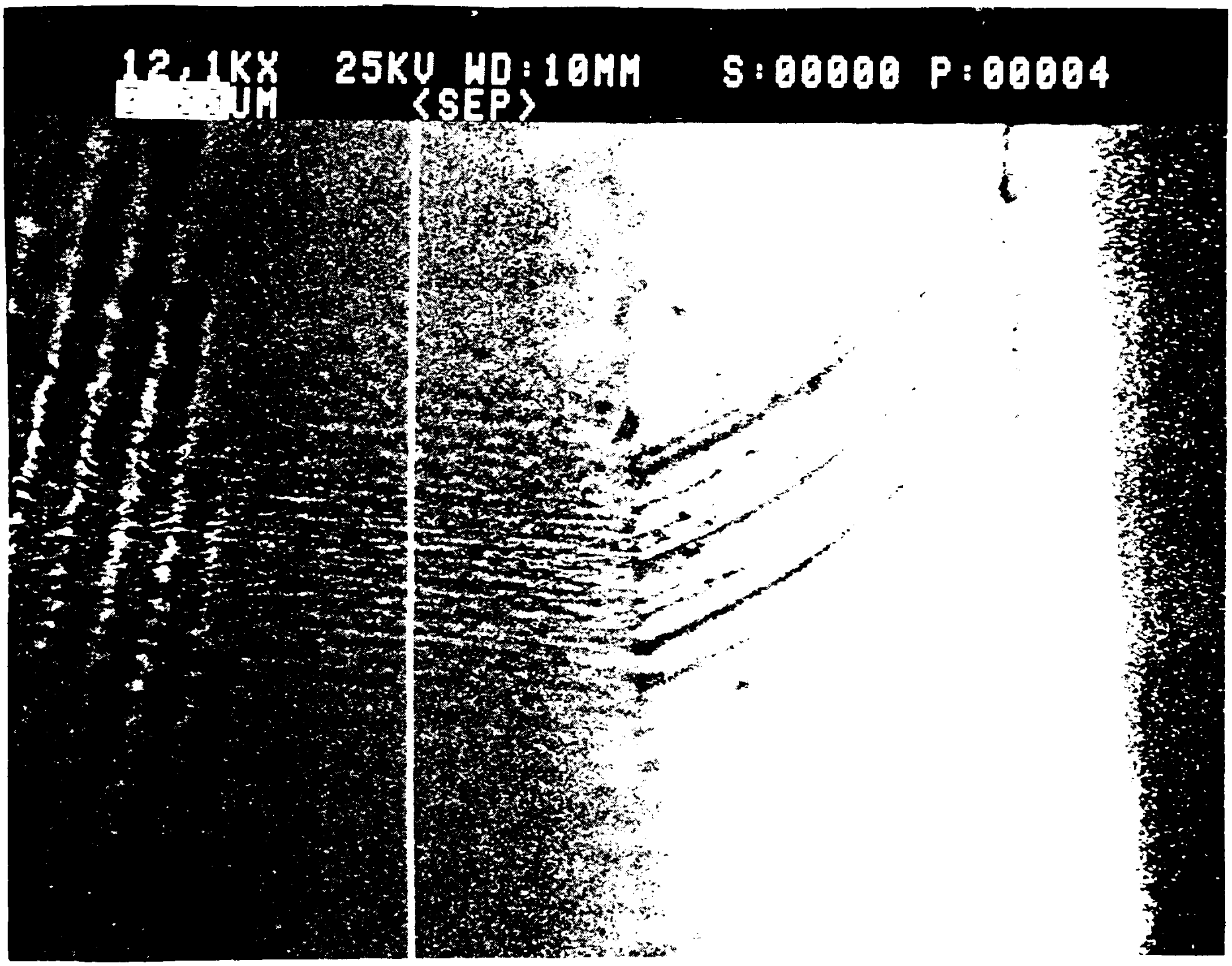
Presentation at DoD Fiber Optics Conference Paper

For the DoD Fiber Optics Conference a sponsor initialized presentation is scheduled March 21. 1990 . As prepared the paper will present the achievements obtained in this research and development effort. The significance of scaling with the chip area for truly edge-independent lasers for large scale opto-electronic integration is presented along with the compromise concept of a half-ring laser that utilizes one cleaved crystal facet for both ends of the resonator. The presentation includes our results of half-ring lasers with radius of curvature of 100 μm and 150 μm with best threshold currents of 6.8 mA and best frequency responses of 6.5 GHz at the -3 db point at 40 mA injection current. The full ring laser threshold of 17.5 mA as well as the concept of the fully integrated vertical emitting ring laser are to be presented.

Other Activities

Several two step growths of the original buried heterostructure half-ring lasers where completed and devices investigated. The measurements indicate the severe demand on the processing for this kind of laser structure resulting in low yield. Testing many half-ring structures with radius of curvature of 50 μm did not reveal operating lasers. The original processing method seems not suitable for such small a radius of curvature.

The paper for publication in a technical journal is submitted for review to Applied Physics Letters. A copy will be send to the sponsor to obtain formal clearance separately from this report.



[illegible] SEM of etched grating (left) next to simulated active region of ring laser (right) showing the short transition [illegible]

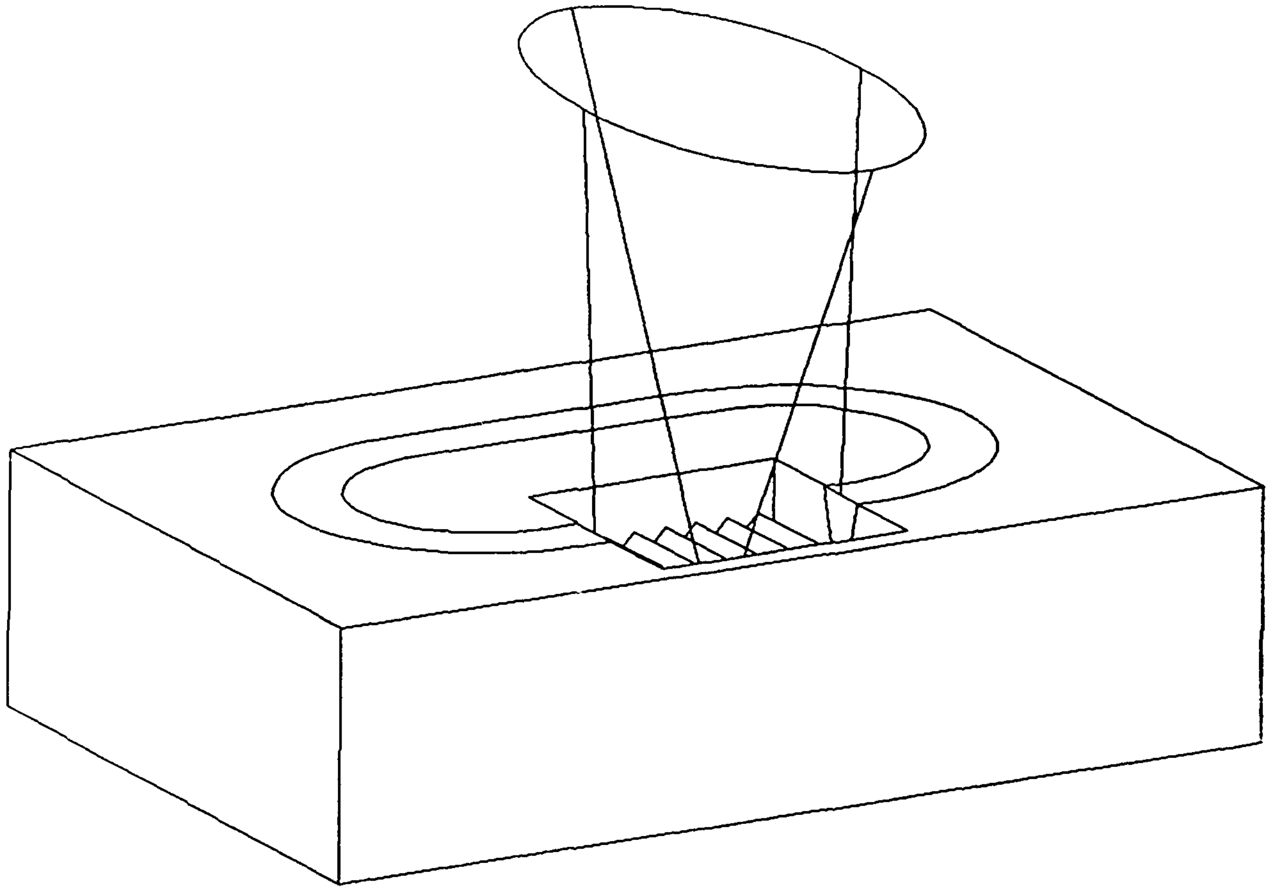


Figure 2. Overall structure of grating coupled vertically emitting integrated ring laser.